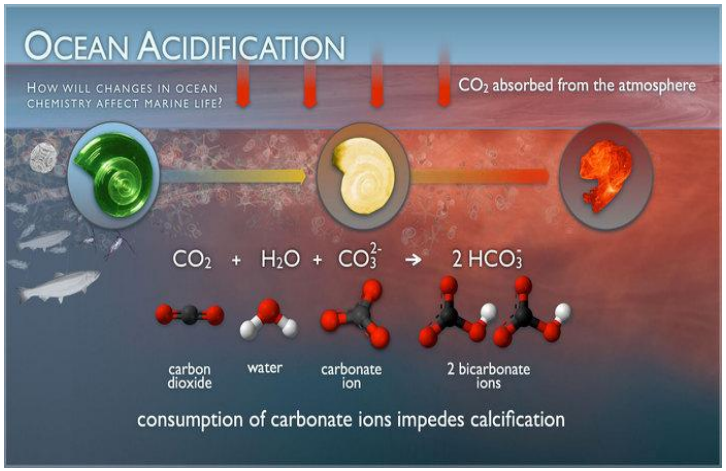
# Other Process Research

Ed Farley

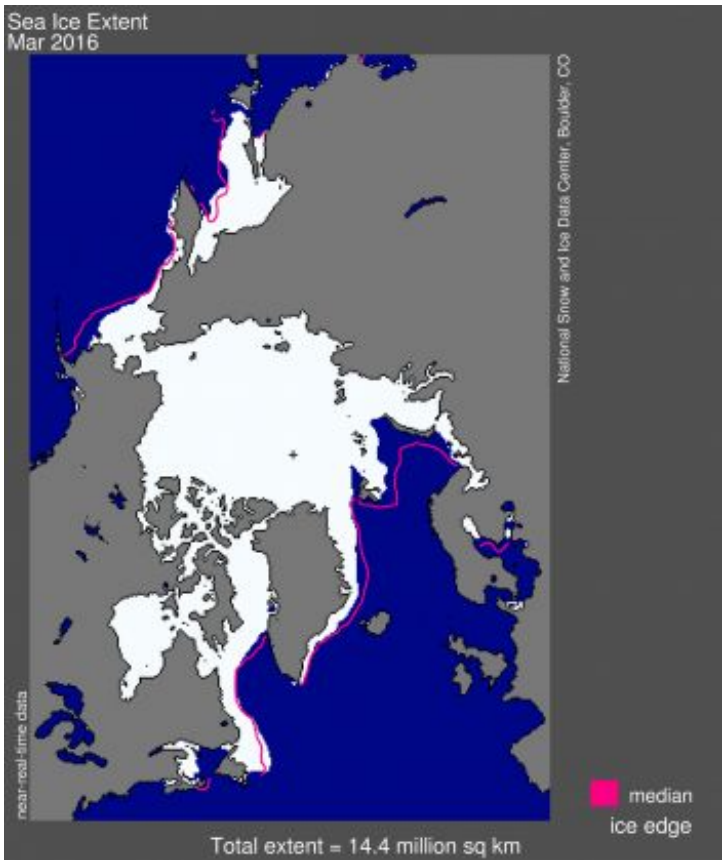
NOAA FISHERIES
Alaska Fisheries Science Center

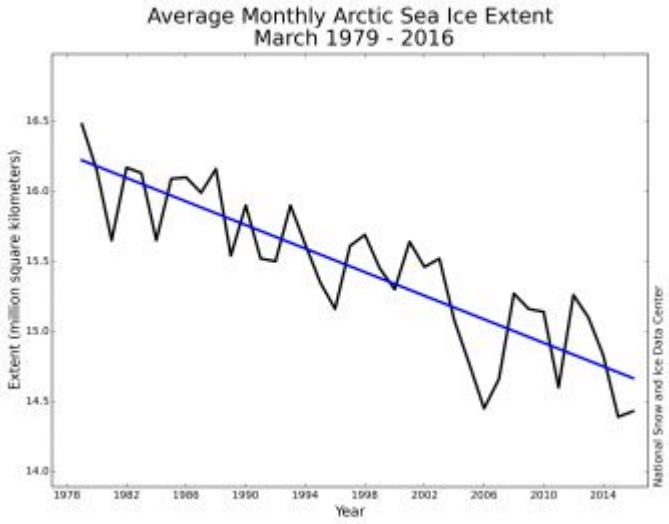
Ecosystem Science Review
Juneau, Alaska
May 2-6, 2016

# Other Projects

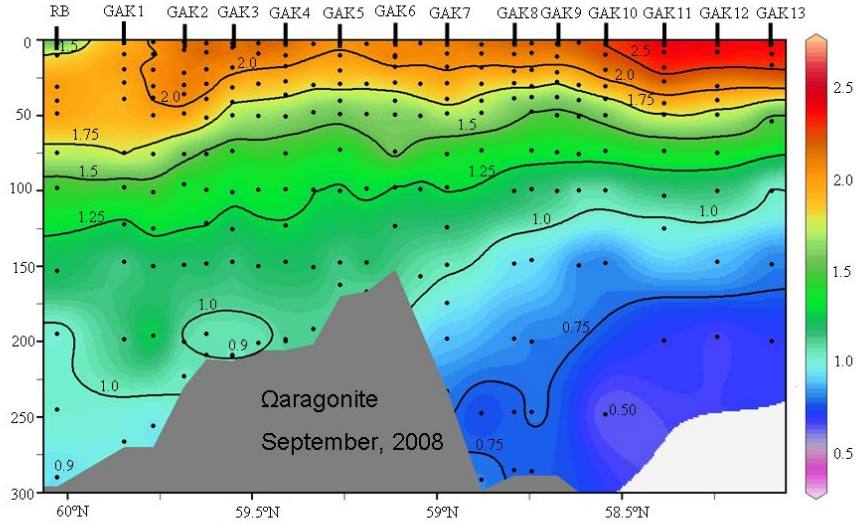



1) Ocean Acidification
2) Loss of Sea Ice
   - Arctic – winners and losers
   - Will fish move norths?



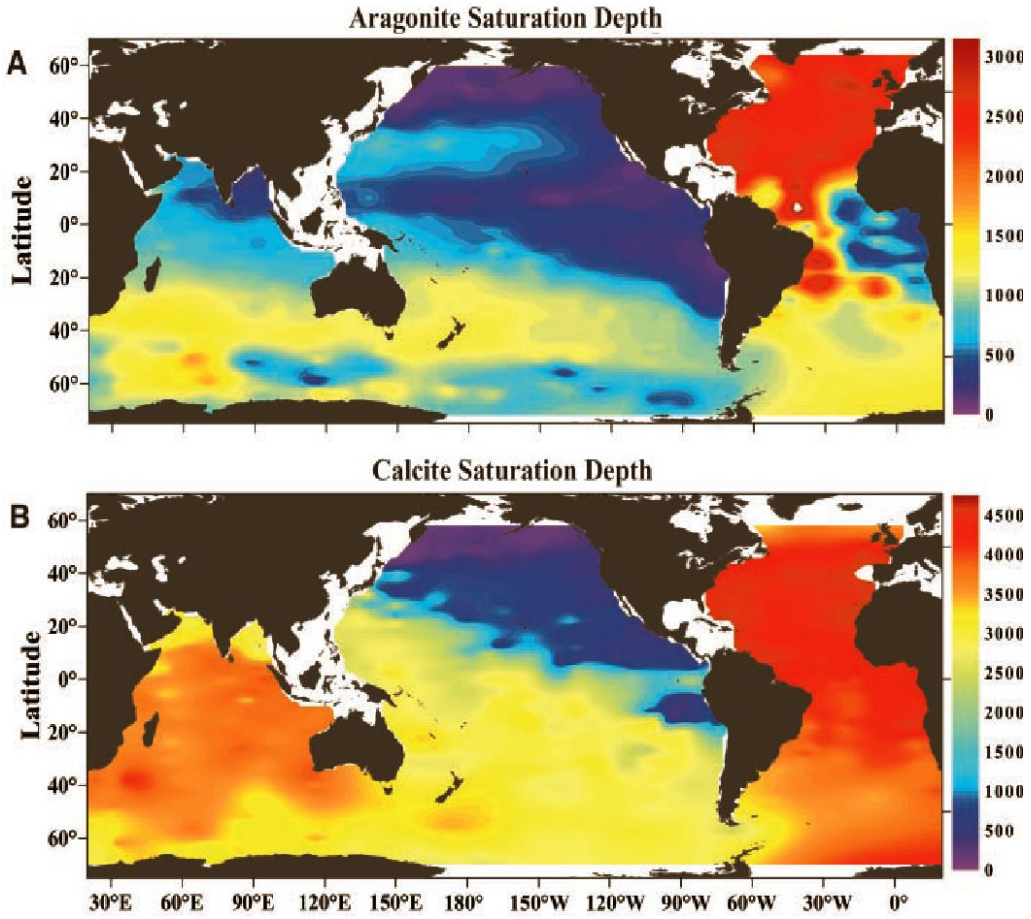



# North Pacific fisheries are at risk because calcium carbonate saturation horizons are relatively shallow there




Depth of undersaturated waters (aragonite) at 147 Deg W *J. Mathis, NOAA, Univ. Alaska*

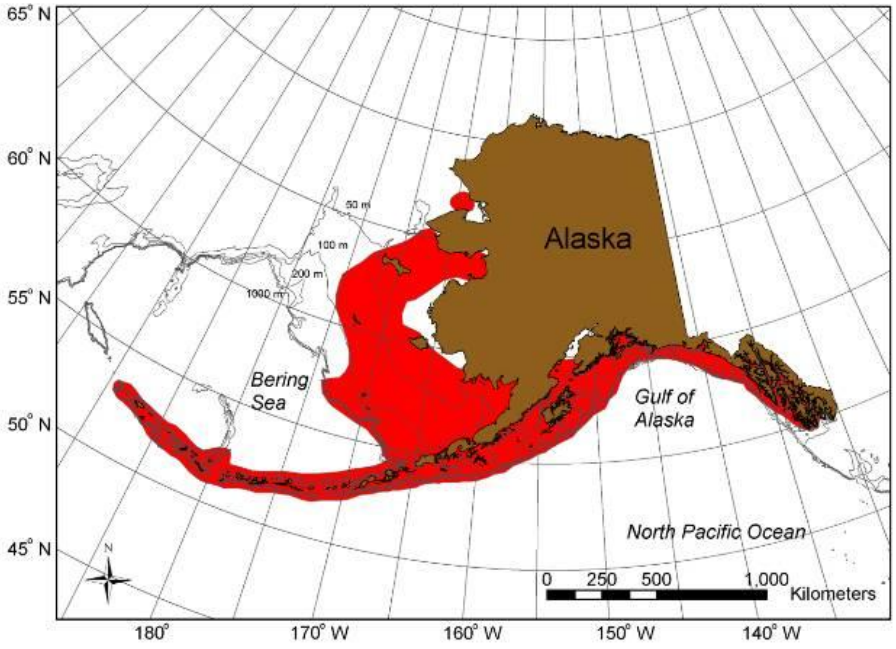
Jeremy Mathis



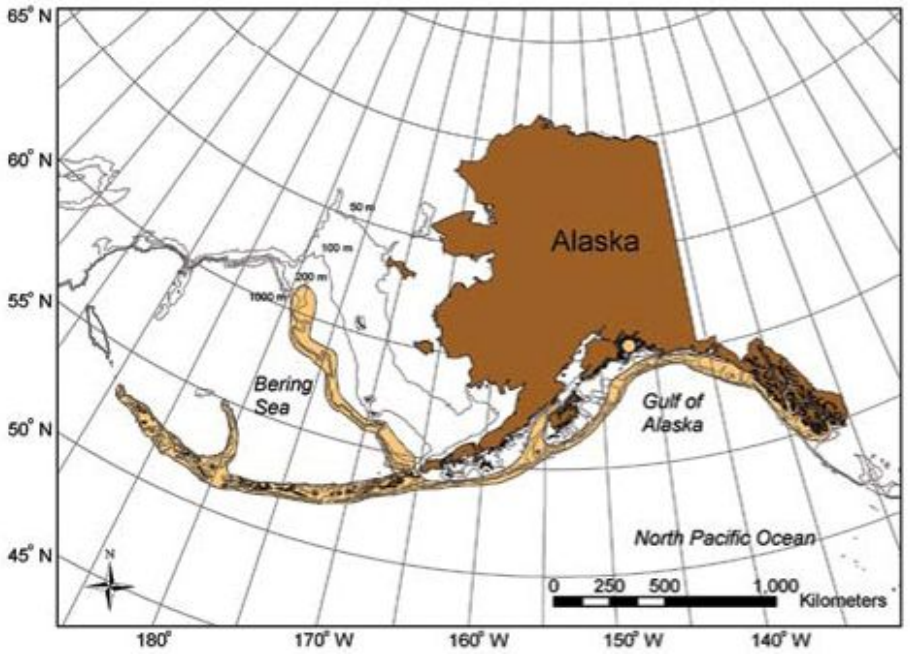

Feely et al. 2004. Impact of anthropogenic $CO_2$ on the $CaCO_3$ in the oceans. Science 305: 362-366.

# Ocean Acidification Effects on Crabs

## Red king crab distribution




## Golden king crab distribution



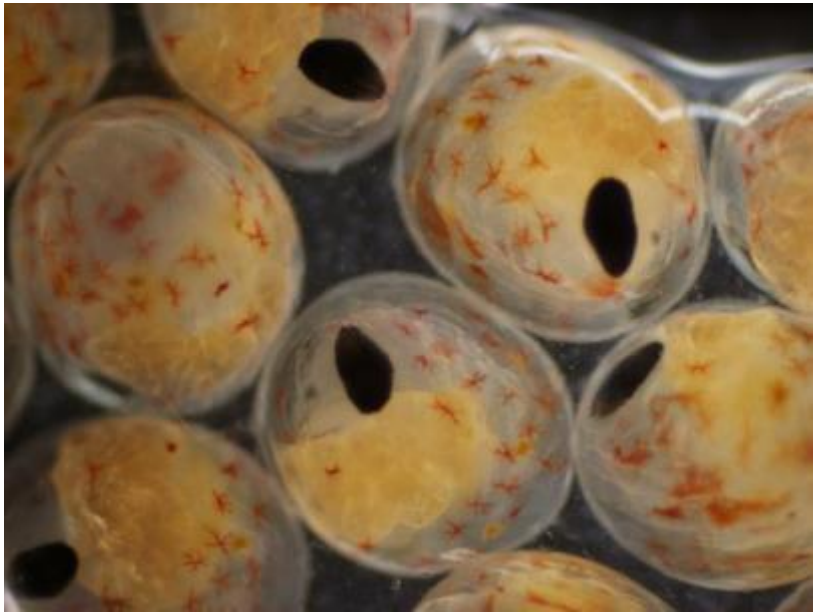
Bob Foy

# Alaska King Crab

## Kodiak Fisheries Research Center Seawater Facility

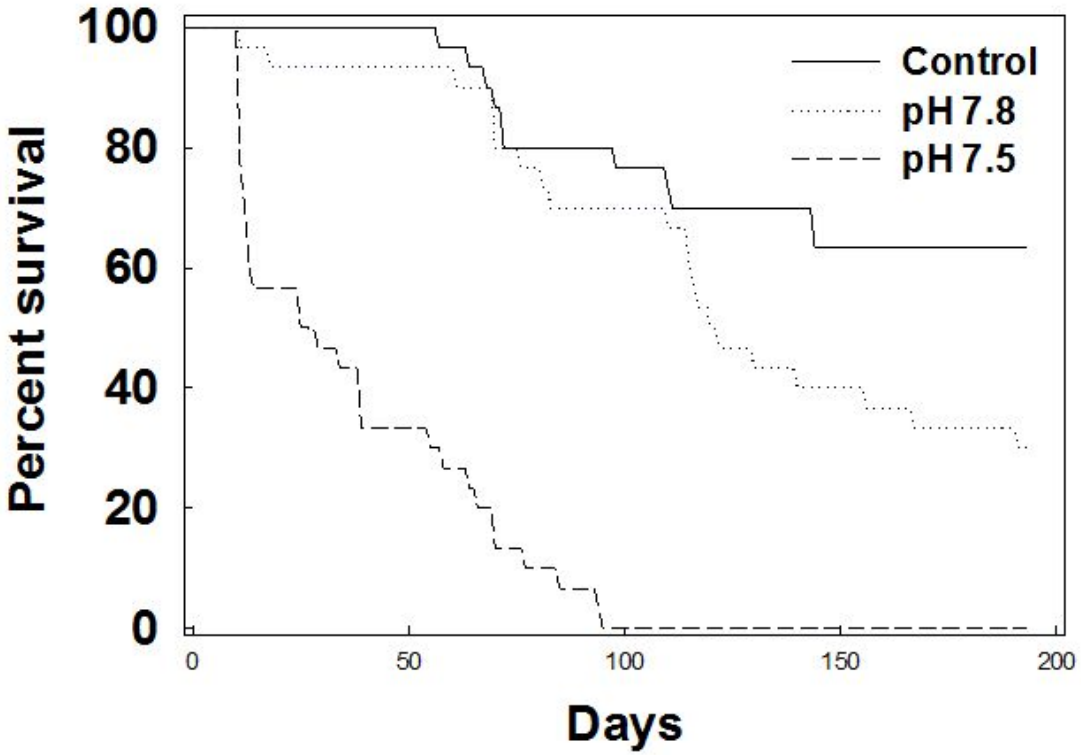
# Red King Crab Embryos

- Adult females collected from Bristol Bay fishery
- pHs: Ambient and 7.7 (~2100)
- **Decreased pH associated with smaller eggs and embryos and larger yolks.**



# Red King Crab Juveniles

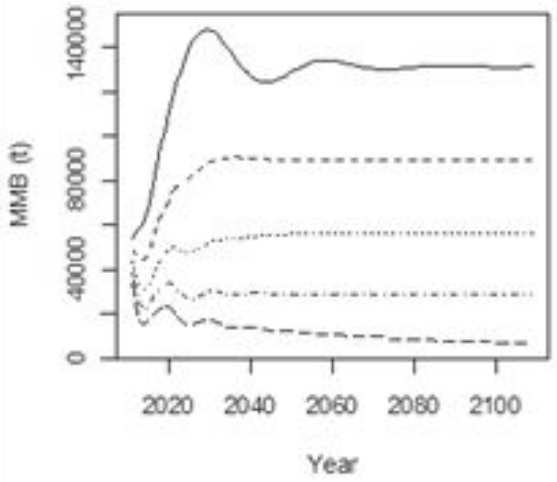
- Crabs held in individual containers
- Control, pH 7.8, pH 7.5
- 30 crabs/treatment
- **Survival decreased with decreasing pH**

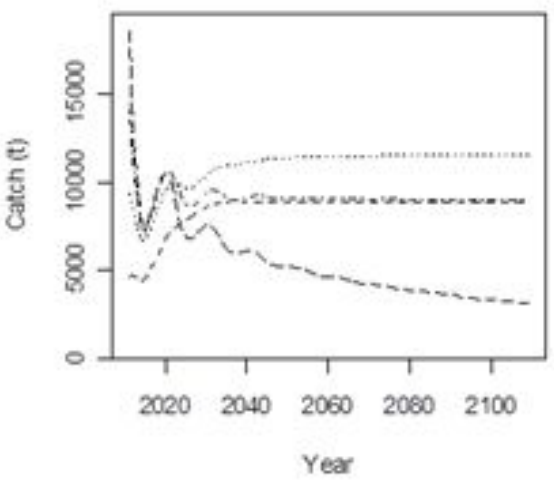



Experiments also conducted on larvae

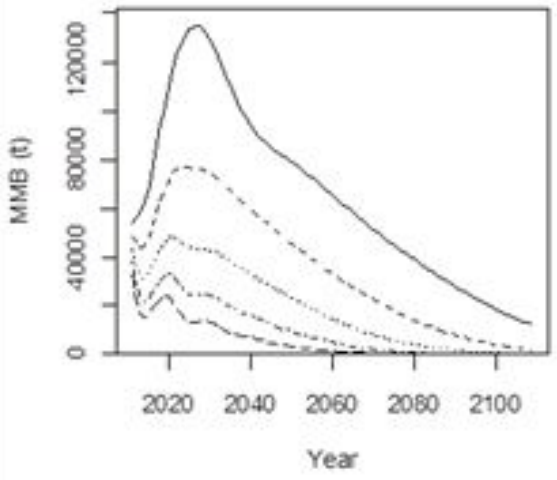
# King Crab Population Effects: Red King Crab

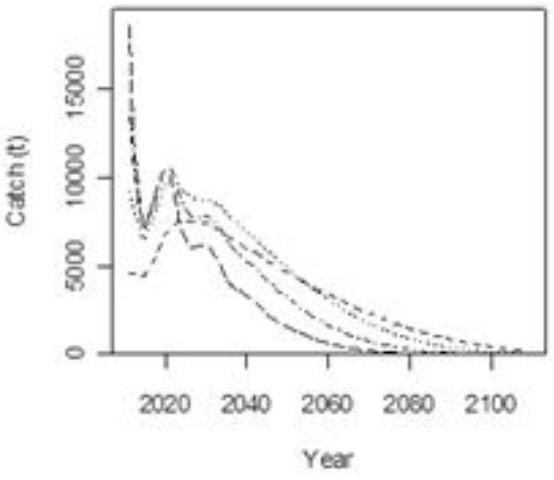
stock dynamics without OA




stock dynamics **with** OA




- **At a pH of 7.8 stocks and catches decline**
- **Under current catch levels fishery would be closed in about 2100**

Mike Dalton

Punt, Poljak, Dalton, Foy. 2014. Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay. **Ecological Modeling. 285: 39-53**.

Tom Hurst

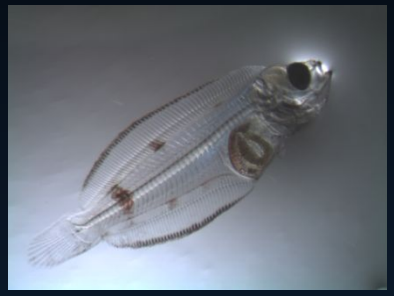
# Alaska Groundfish

## Newport Seawater Facility

# Alaska groundfish comparison

Based on laboratory experiments exposing eggs and larvae to elevated $CO_2$ in laboratory experiments.

Northern rock sole



More sensitive

To 1600 µatm $CO_2$ ; to 60 days post hatch

- No effect on hatch success or size at hatch
- Reduced growth and condition in post-flexion fish
- Trend toward higher mortality at high $CO_2$ levels

Hurst et al. 2015

Walleye pollock

Resilient

To 2100 µatm $CO_2$ ; to 28 days

- No effect on survival to hatch
- Slight growth improvement at intermediate $CO_2$
- No $CO_2$ effect on survival

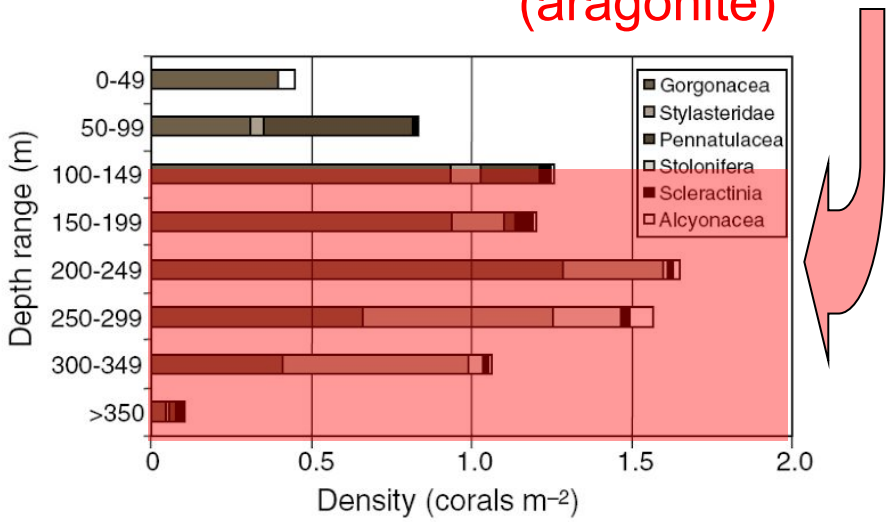
Hurst et al. 2012 & 2013

The direct effects of OA on growth energetics of walleye pollock and northern rock sole appear to be minor, but are not equal.

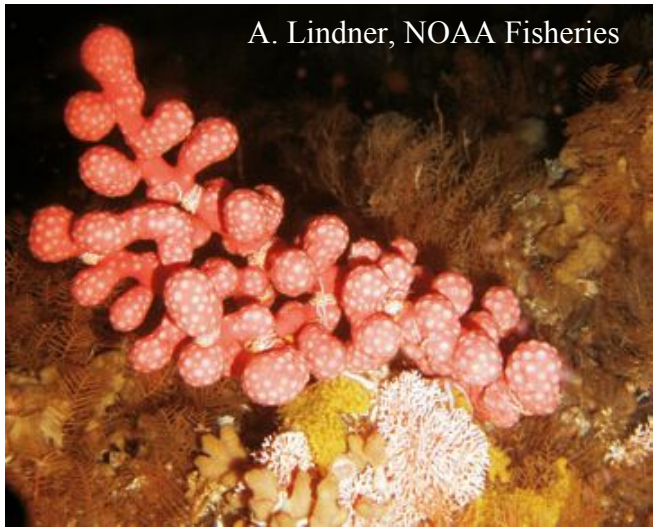
# Coldwater Corals

Depth distribution of Aleutian corals.

Undersaturated (aragonite)




Stone, RP. 2006. Coral habitat in the Aleutian Islands off Alaska: Depth distribution, fine-scale species associations, and fisheries interactions. Coral Reefs 25:229-238.



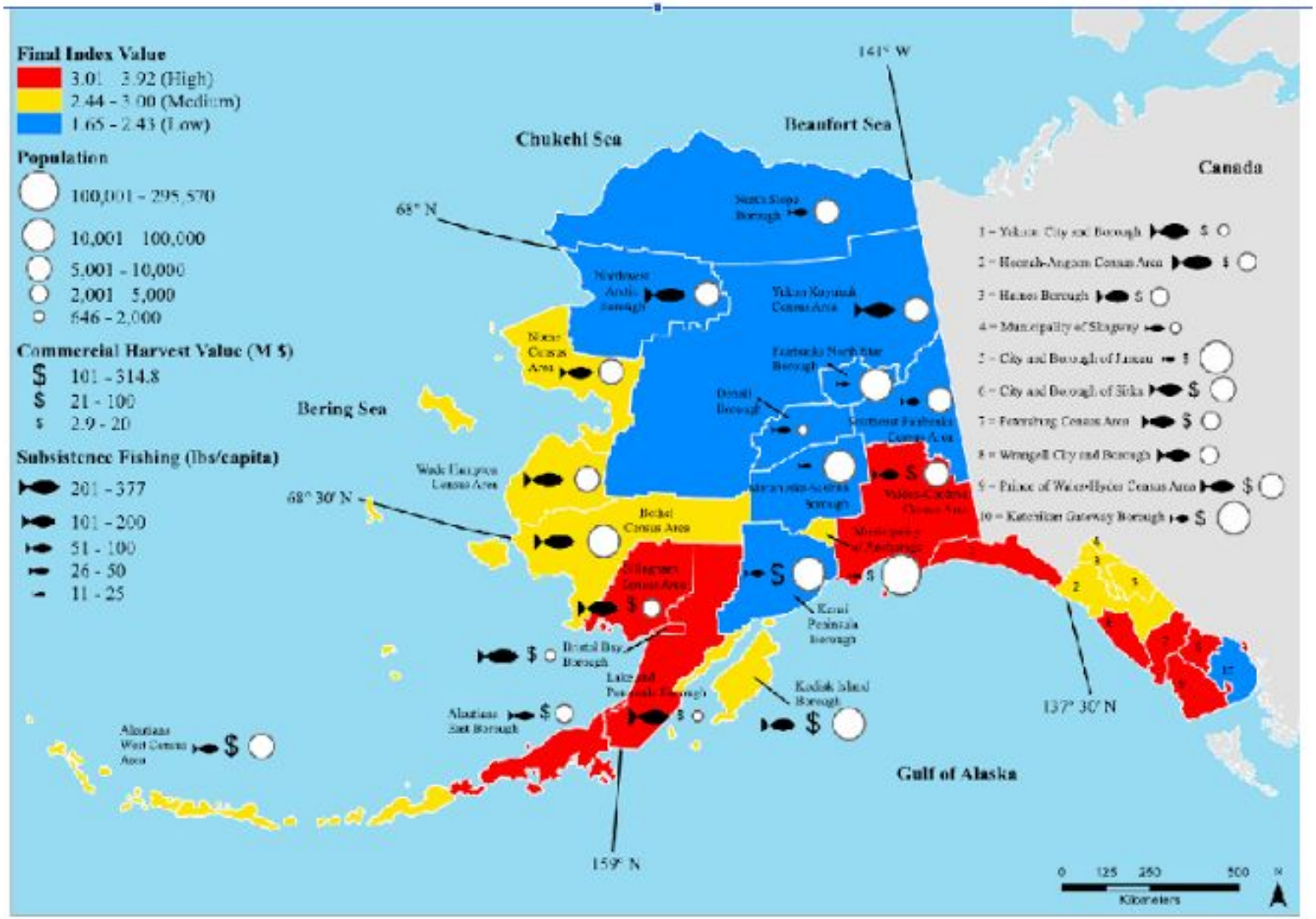

Bob Stone (holding red tree coral)

<u>Projects</u>:

Coral mineralogy catalog

Experiment *Primnoa* spp. (red tree coral)

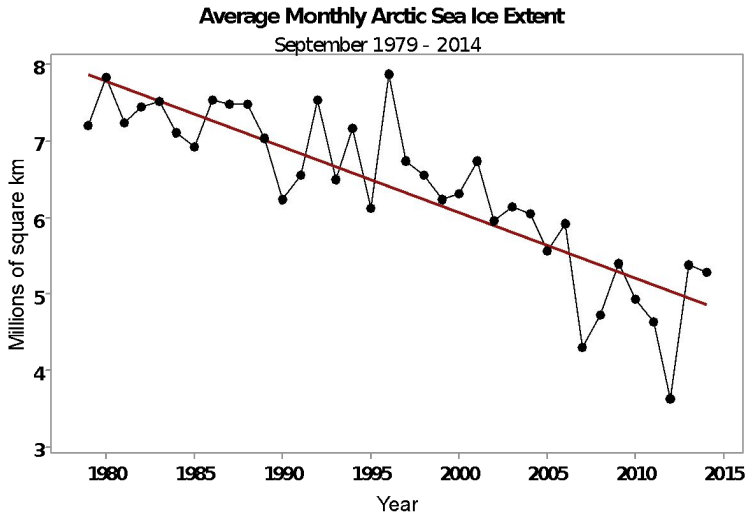
# Ocean acidification risk index



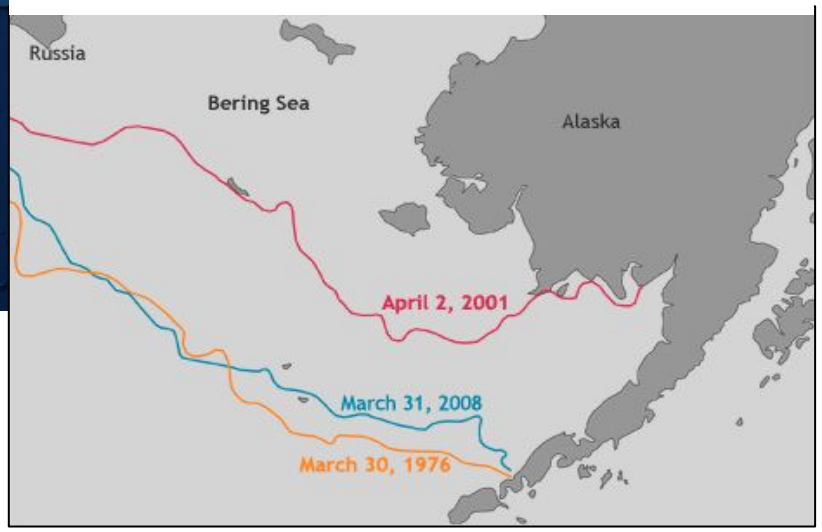

Mathis, J.T., et al. Ocean acidification risk assessment for Alaska's fishery sector. Prog. Oceanogr. (2014), http://dx.doi.org/ 10.1016/j.pocean.2014.07.001

# Issue: Loss of Sea Ice


Declining Sea Ice Extent (Sept)




Sea Ice Extent/Duration (Spring)

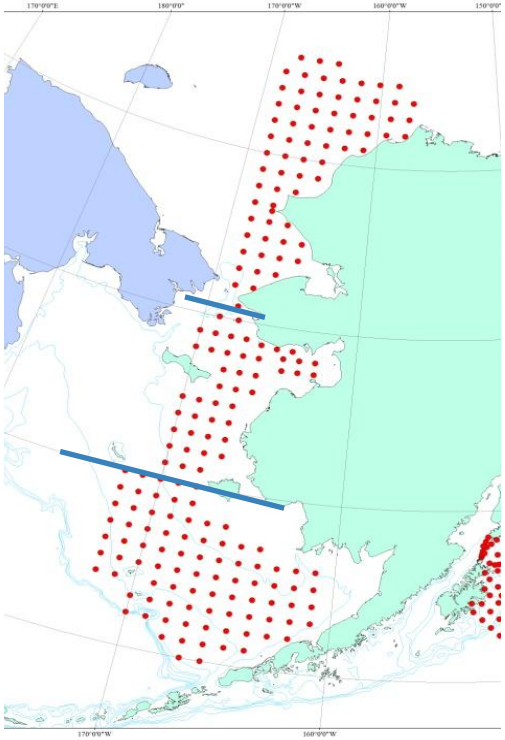


# Strategies to obtain data

August to October
2003, 2007, 2012 to 2013

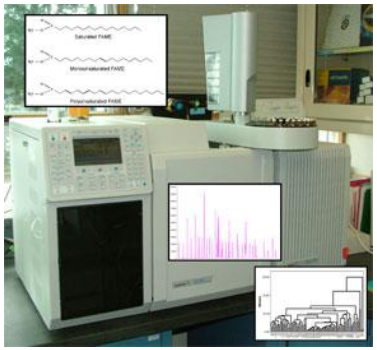
September
2002 to 2015 (2008)

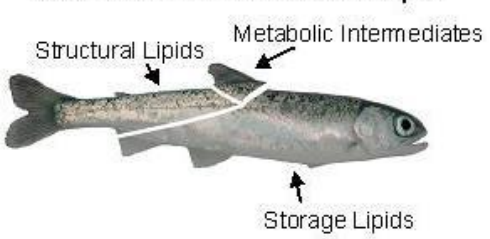
August to October
2000 2012, 2014, 2015



F/V SEA STORM

R/V OSCAR DYSON





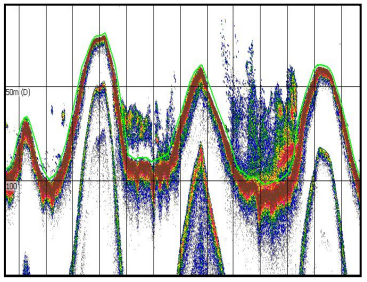

Fish

On board Fish Diet

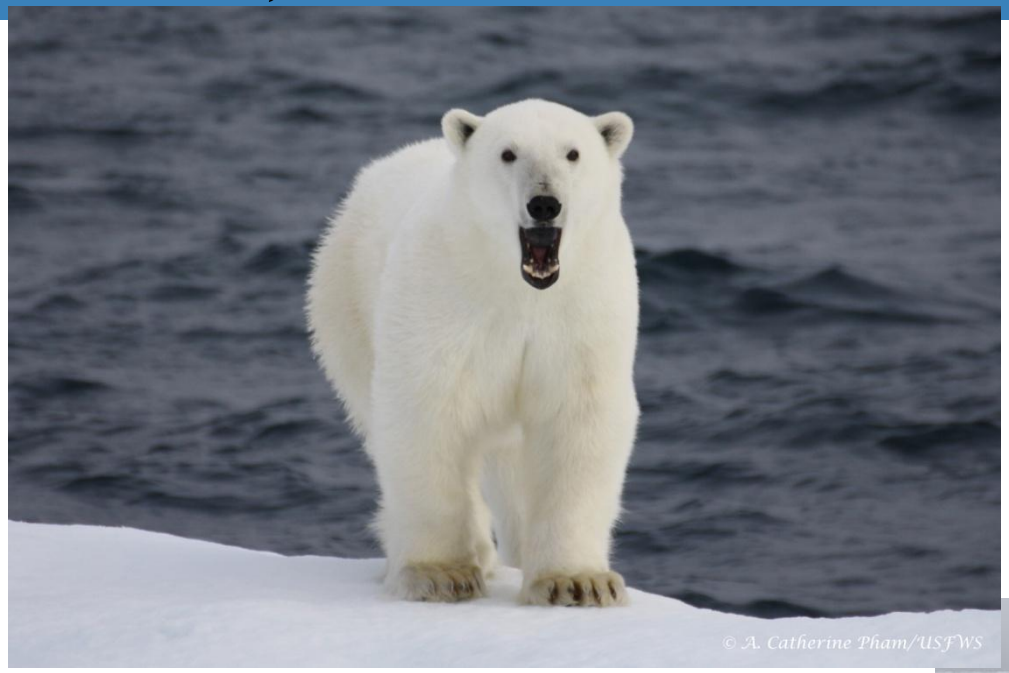
Physical Oceanography

Zooplankton

Acoustics



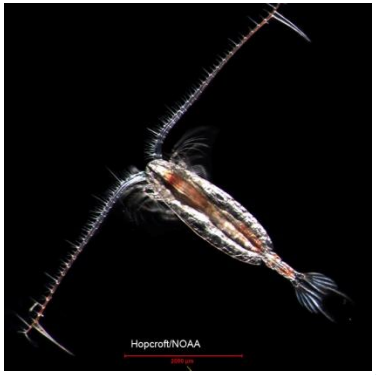
# In the Arctic, It's Survival of the **Fattest**




Polar Bear

Ice seals

## Food Web




Zooplankton

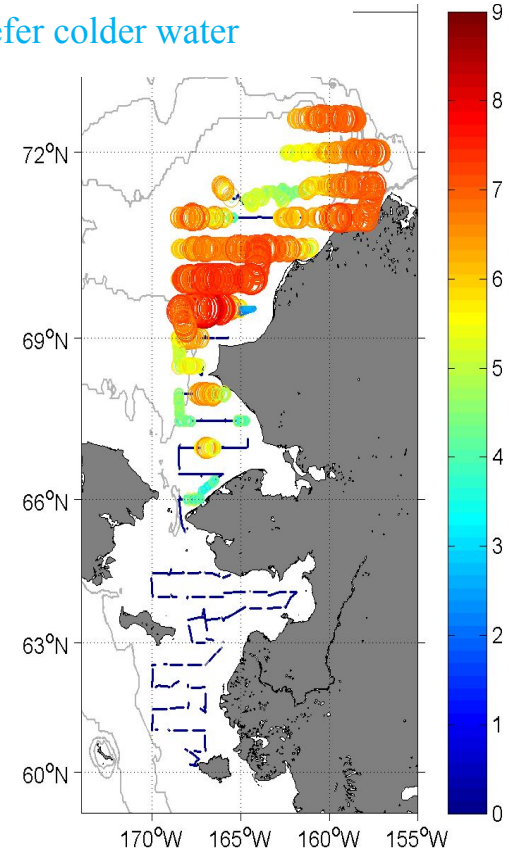
Arctic cod

# Summer Distribution and Abundance of Young Arctic and Saffron Cod

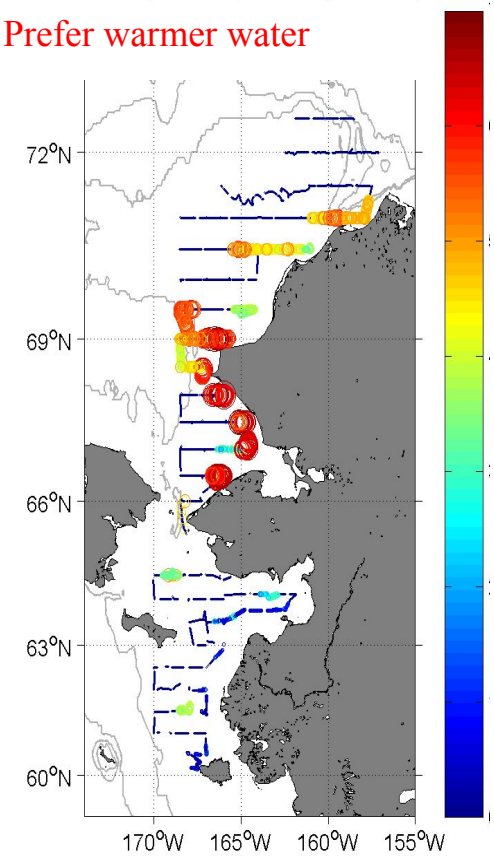
Arctic cod
($2.6 \cdot 10^{11}$ fish)

Saffron cod
($6.5 \cdot 10^{9}$ fish)

Prefer colder water

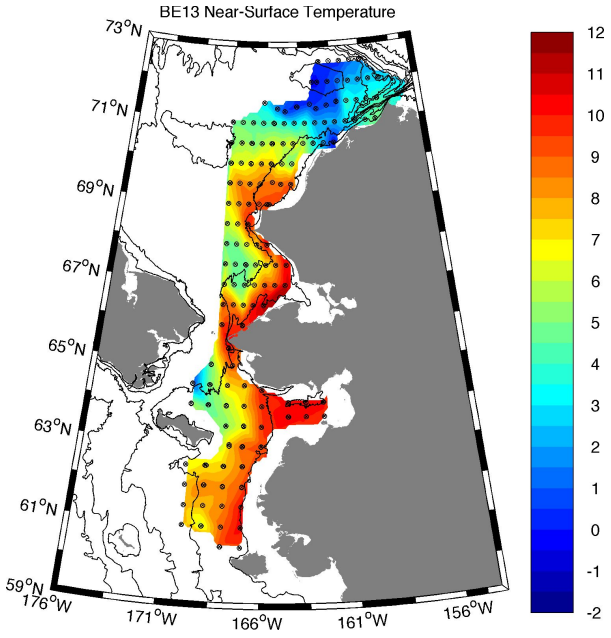



Prefer warmer water



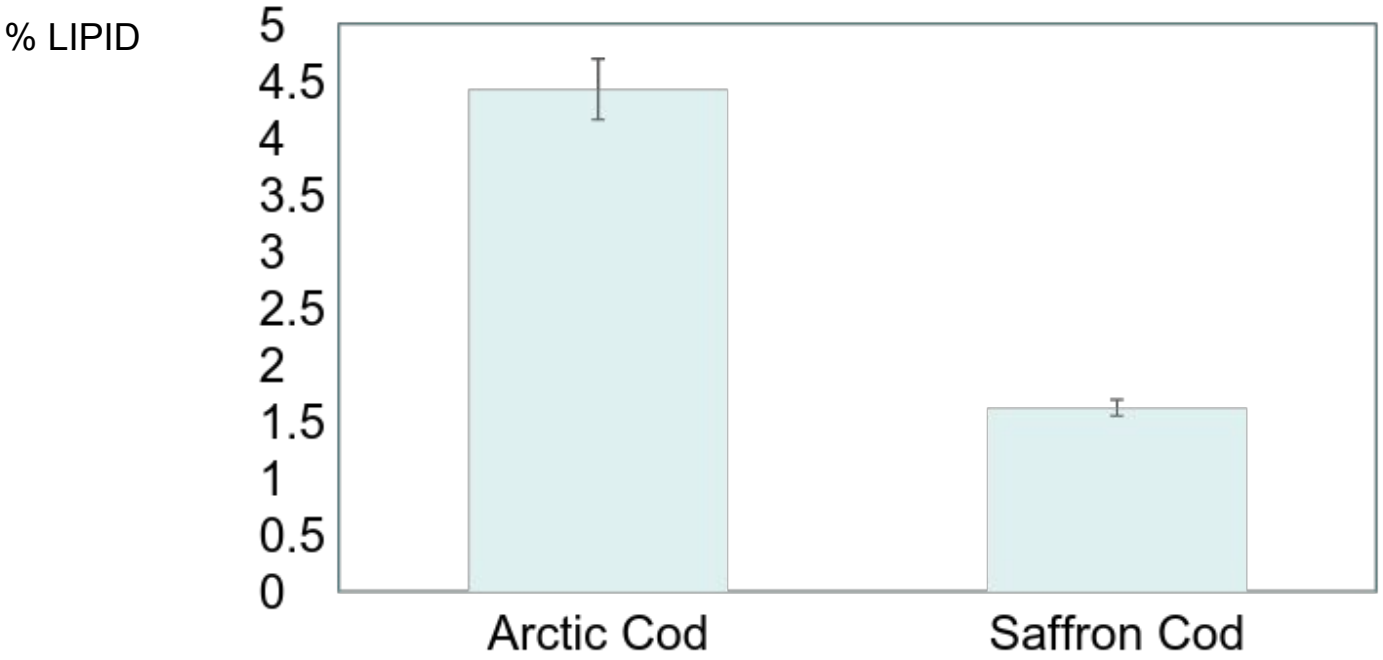

Abundance (Fish nmi$^{-2}$)

Sea Surface Temperatures

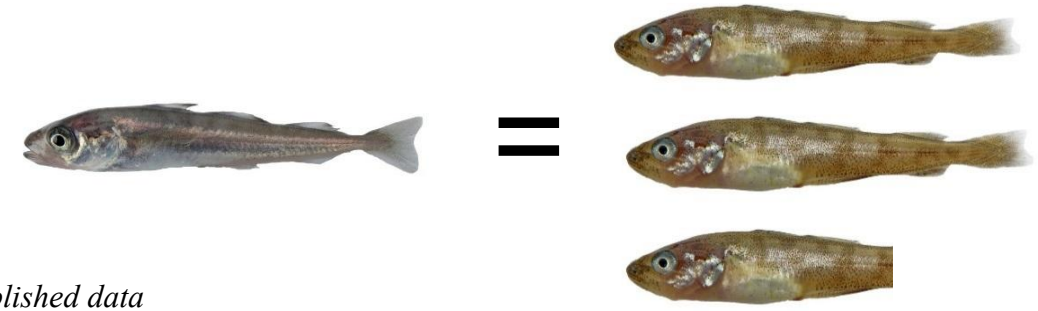



De Robertis, A., K. Taylor, C.D. Wilson, and E.V. Farley. 2016. Abundance and distribution of Arctic cod and other pelagic fishes over the U.S. continental shelf of the northern Bering and Chukchi Seas. Deep-Sea Research II, doi 10.1016/j.dsr2.2016.03.002.

# Fat Content of Cods

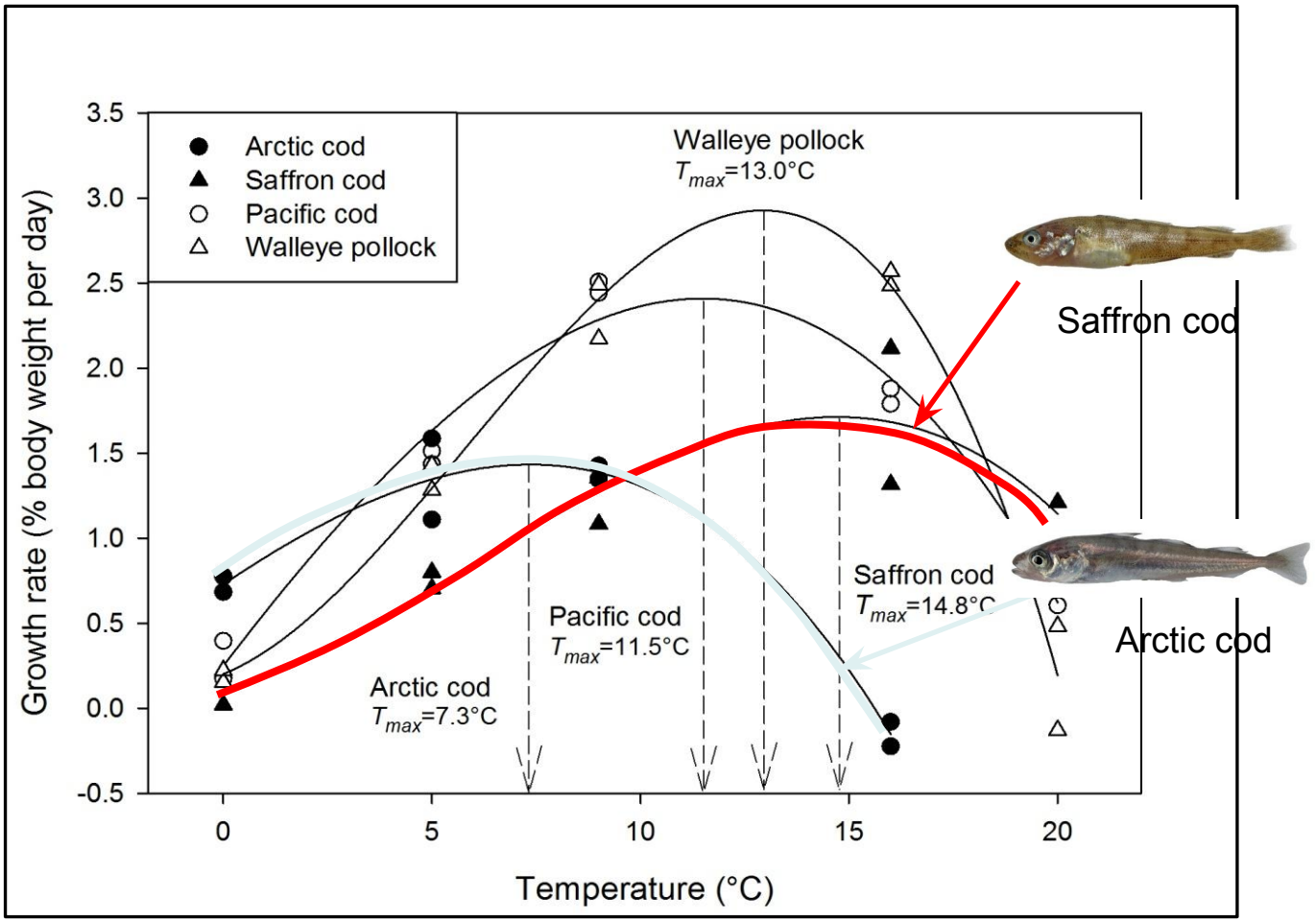



Predators must consume 2.7x the Saffron Cod to get the same lipid as 1 Arctic Cod



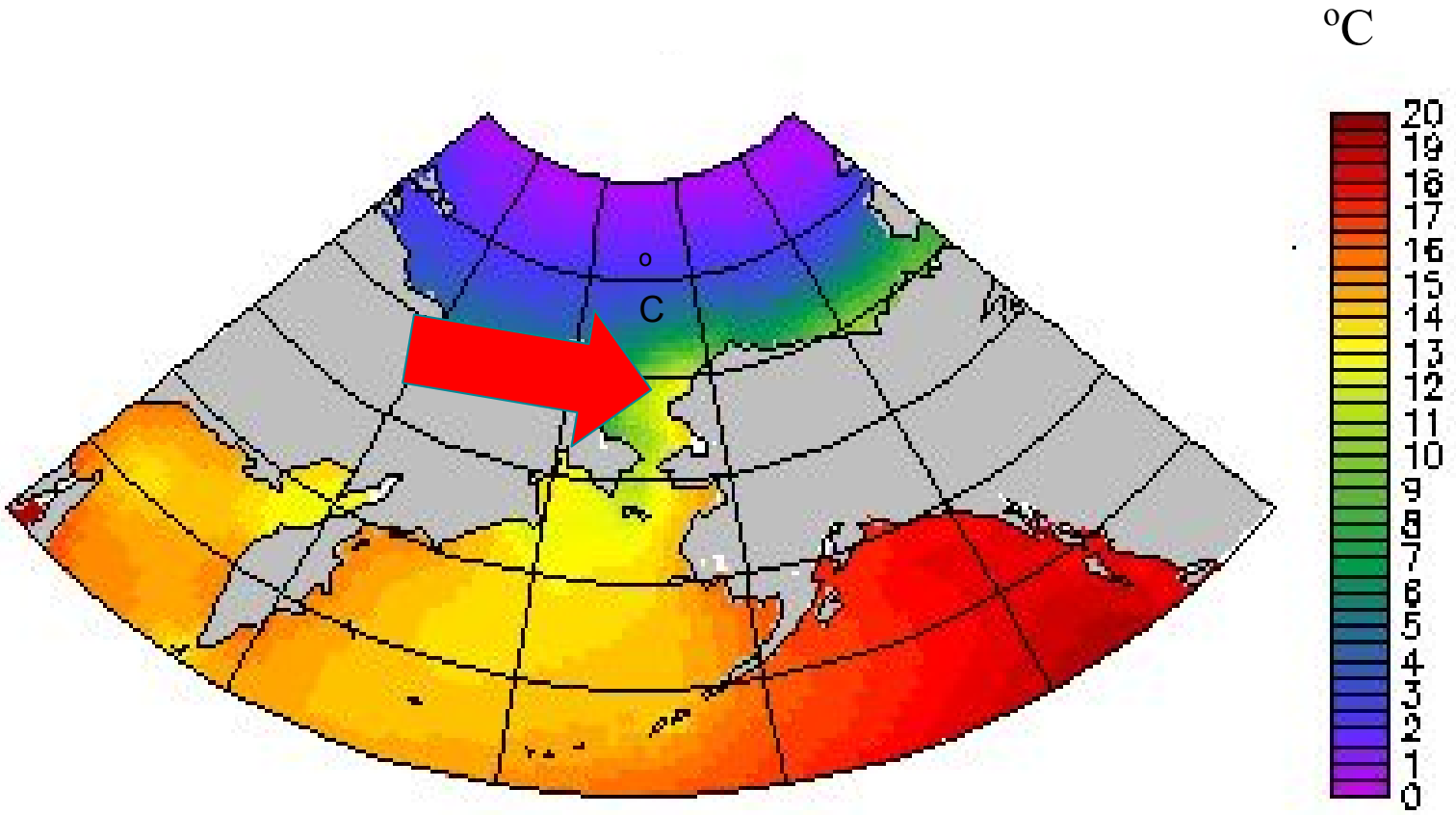

*Heintz & Vollenweider Unpublished data*

# Growth Response in Relation to Temperature




Laurel, B.J., M. Spencer, P. Iseri, and L.A. Copeman. 2015. Temperature-dependent growth and behavior of juvenile Arctic cod and co-occurring North Pacific gadids. Polar Biology DOI 10.1007/s00300-015-1761-5.

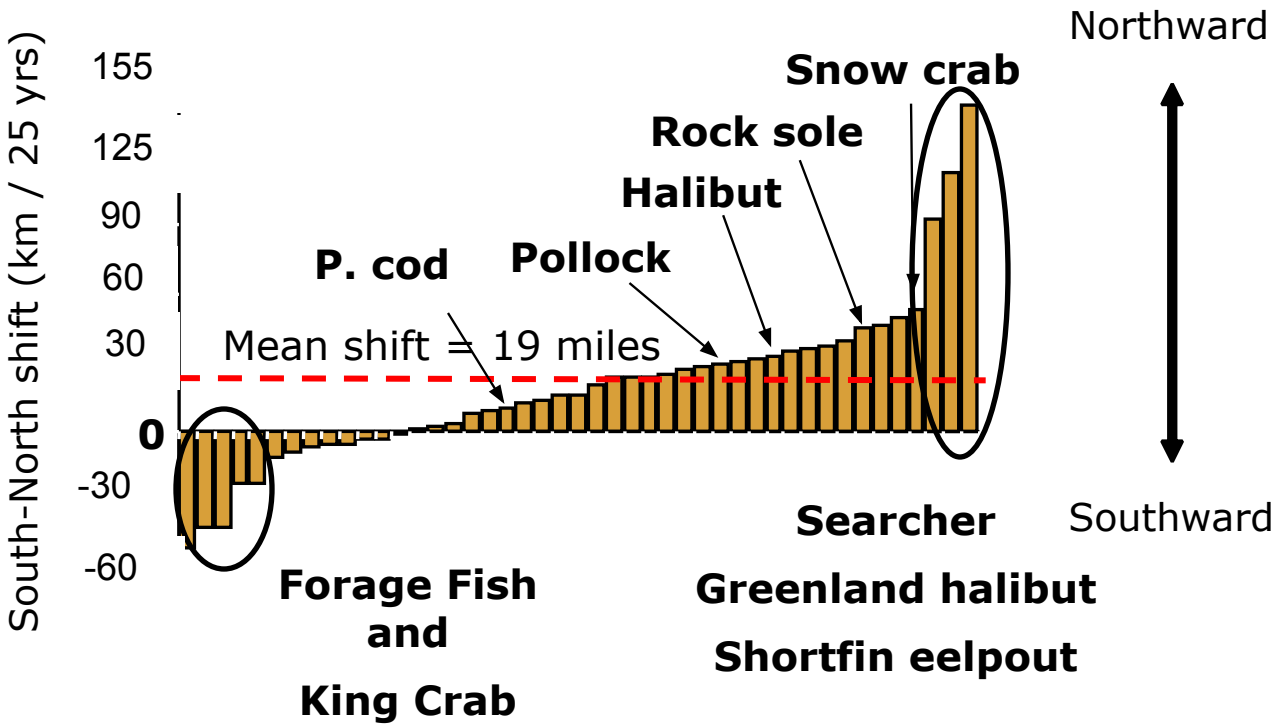
# Summer Sea Surface Temperature Model Projections 2081 to 2100




Water will be too warm for Arctic Cod?

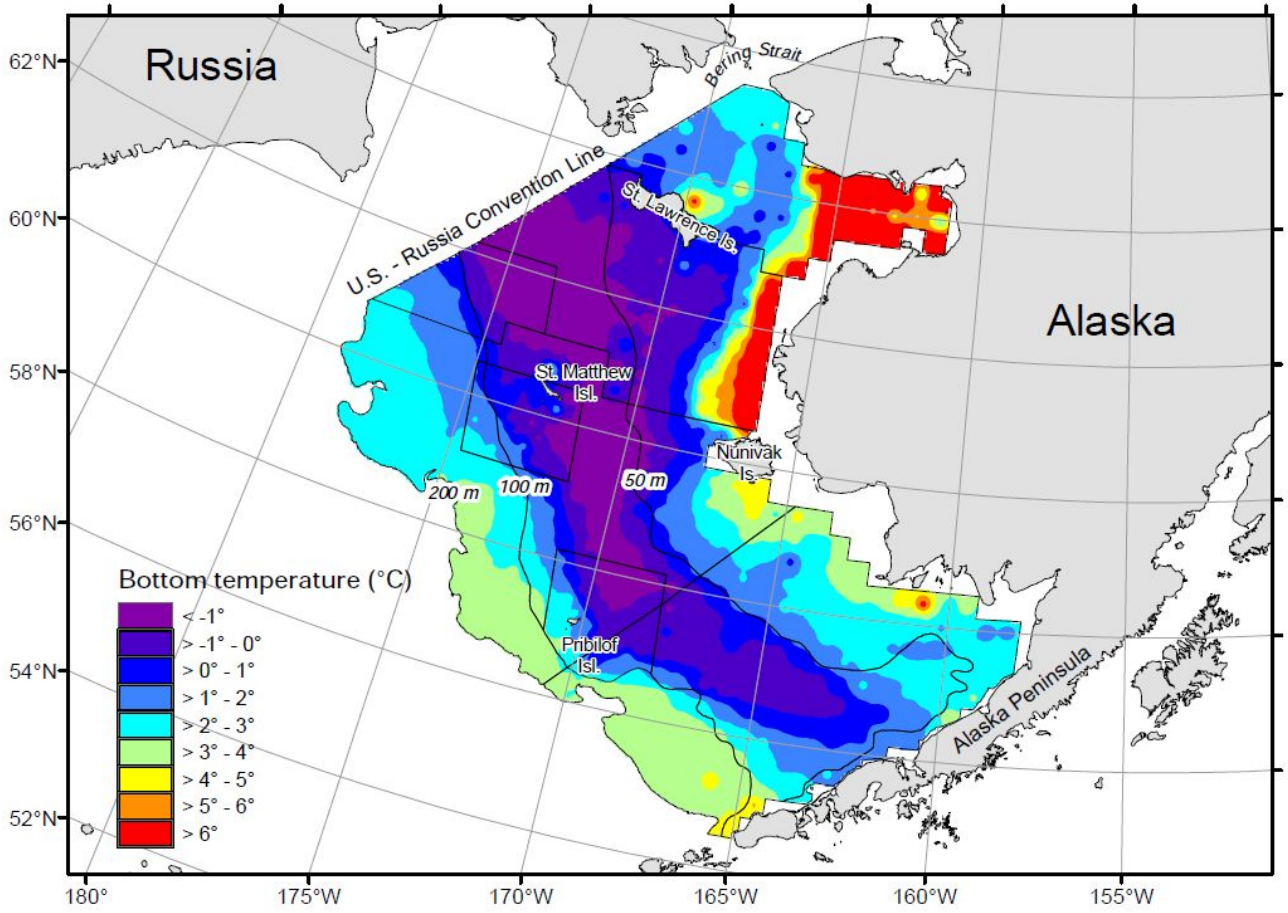
*Courtesy of Muyin Wang, Pacific Marine Environmental Laboratory, Seattle, WA*

# North-South Shifts in Species Distributions in the Southeastern Bering Sea, 1982-2006




Mueter, F.J., and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the eastern Bering Sea continental shelf. Ecol. Appl. 18(2).

# Will Southeastern Bering Sea Fish Species Move North With Loss of Sea Ice?



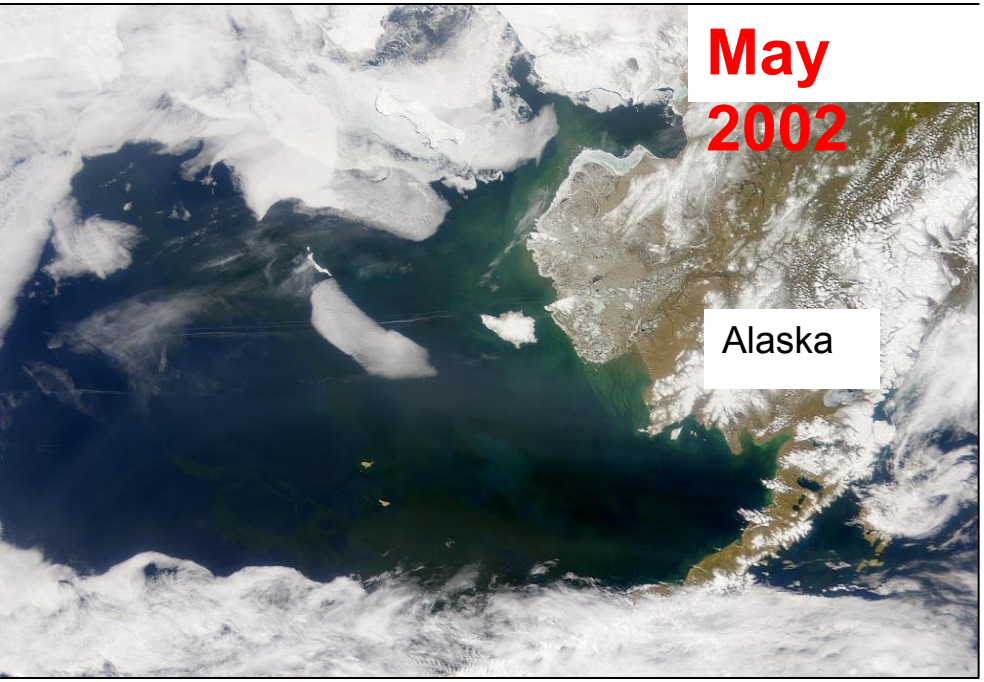

**Fish distribution and movement on the eastern Bering Sea shelf are influenced by bottom temperatures specifically the "cold pool" (<2°C), a remnant of sea ice extent during spring.**

Mueter, F.J., and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the eastern Bering Sea continental shelf. Ecol. Appl. 18(2).

# Spring Ice Extent

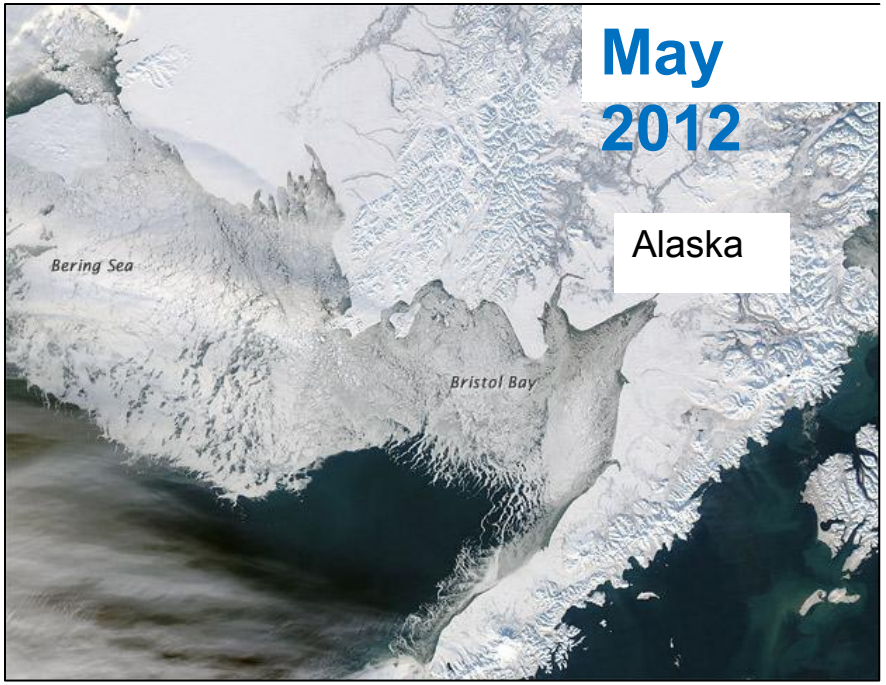
## Early Ice Retreat

2002 to 2005

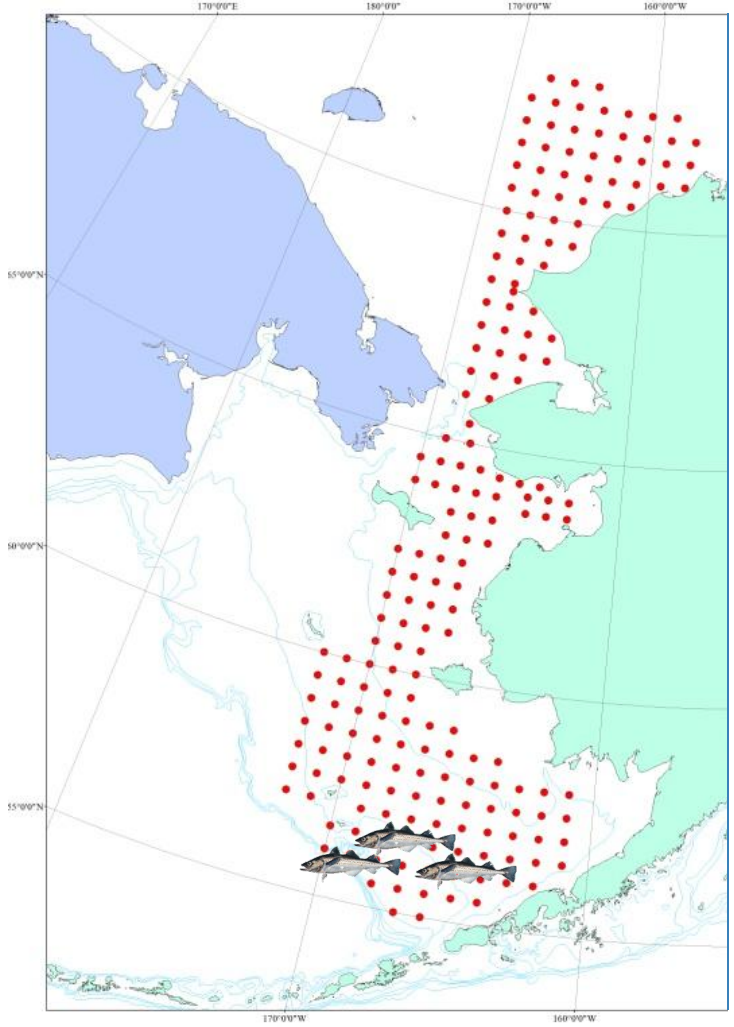


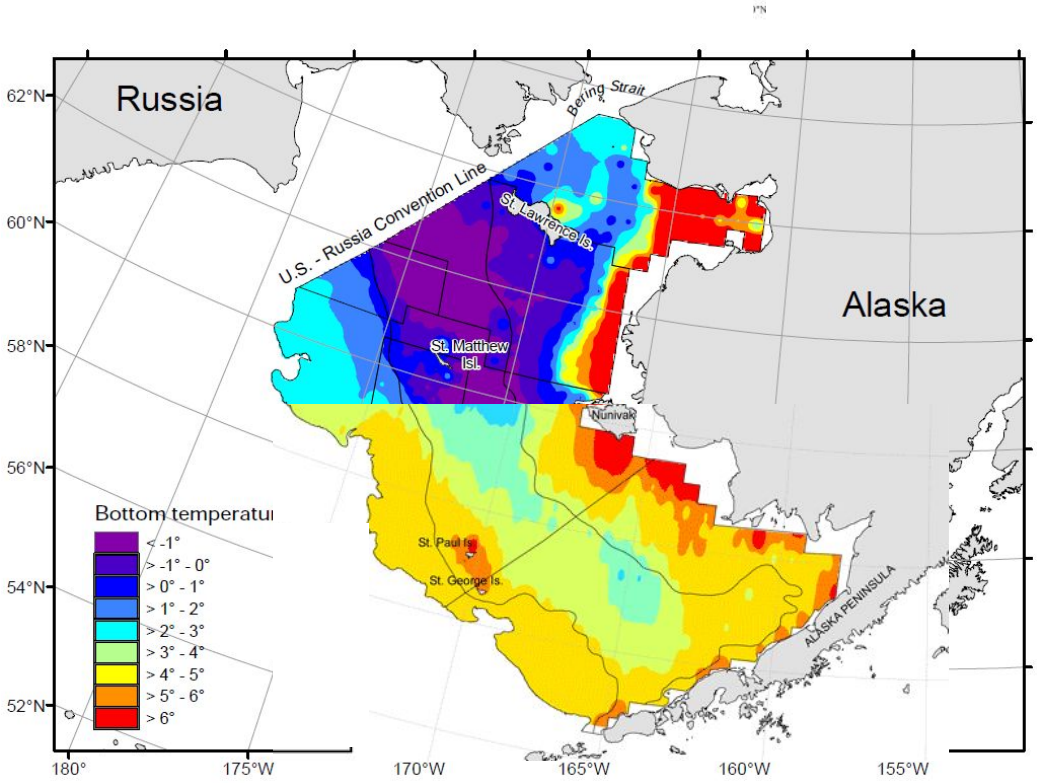

## Late Ice Retreat

2007 to 2012



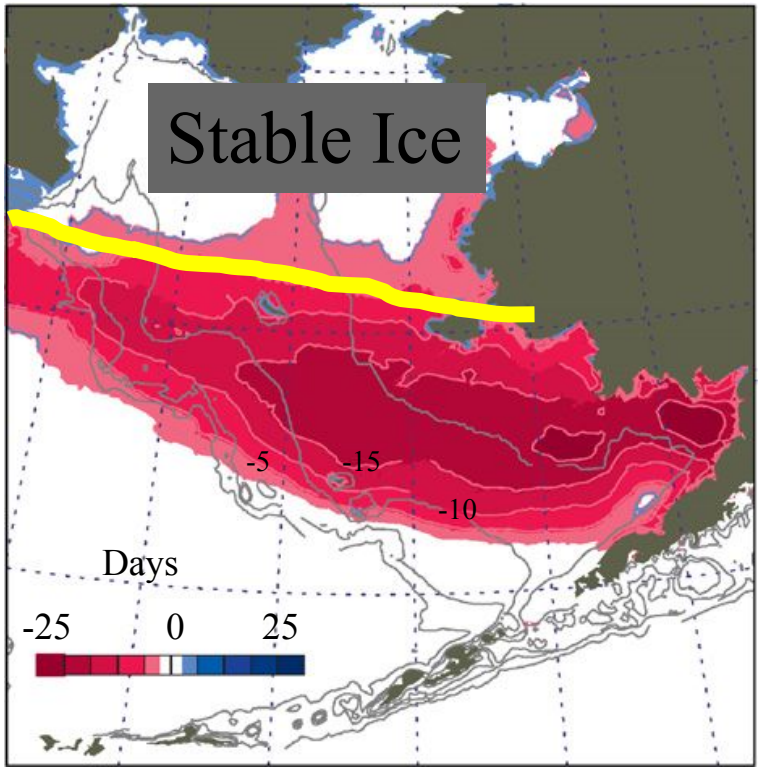
# Will Fish Move North?



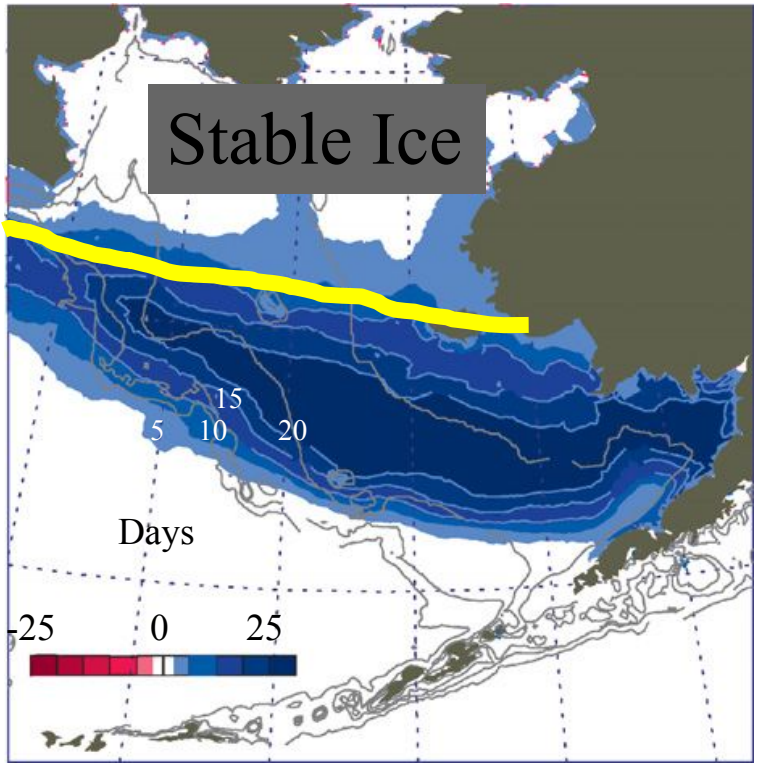


# Future Ocean Conditions: The North Will Remain Cold and Dark

Warm years (2001-2005)

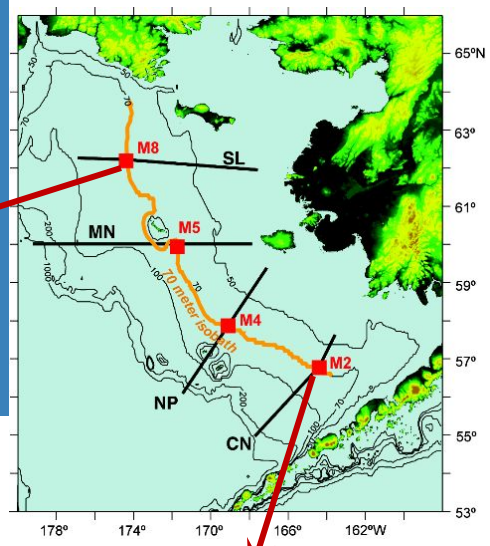


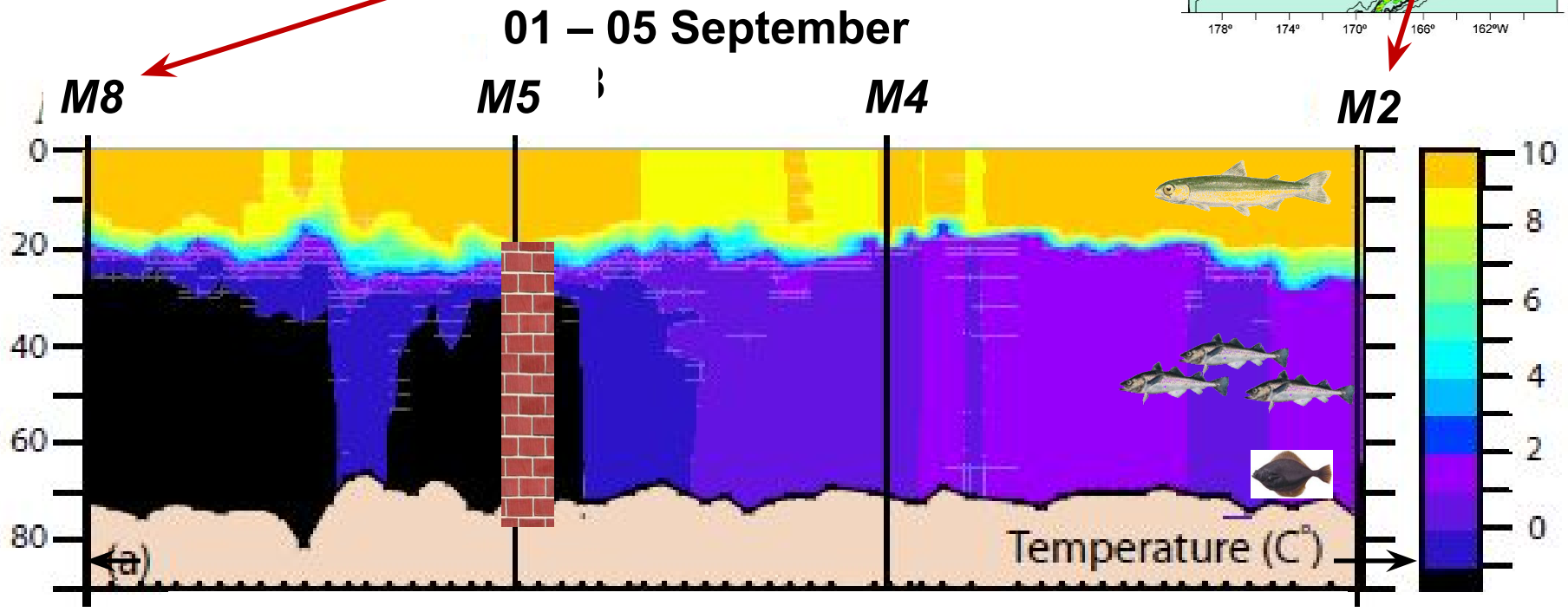

Cold years (2007-2010)




Stabeno, P.J., E.V. Farley, Jr., N.B. Kachel, S. Moore, C. Mordy, J. Napp, J. Overland, A. Pinchuk, and M. Sigler. 2012. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep Sea Res. II 65-70:14-30.

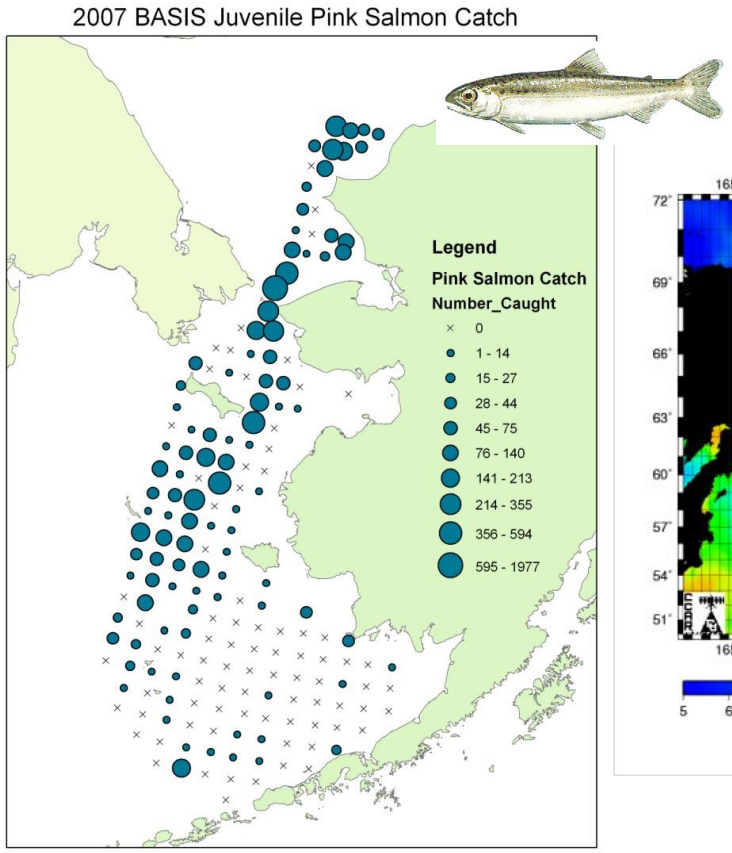
# What is the Potential for Other Fish Species to Move North?

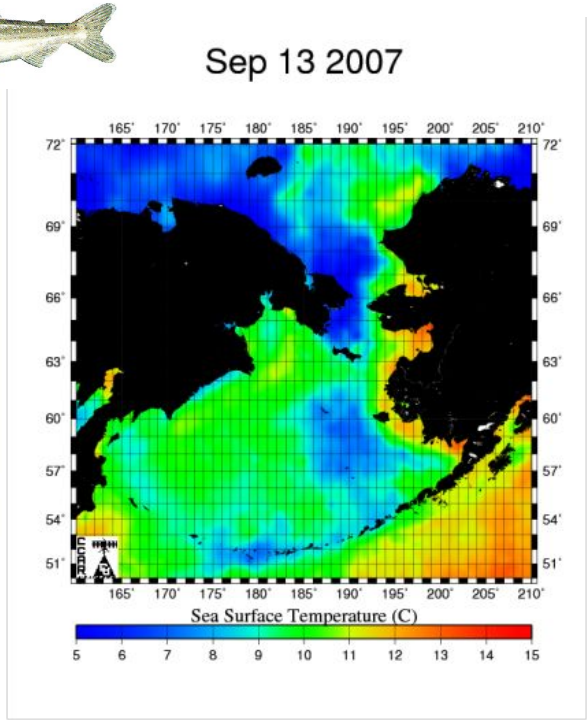


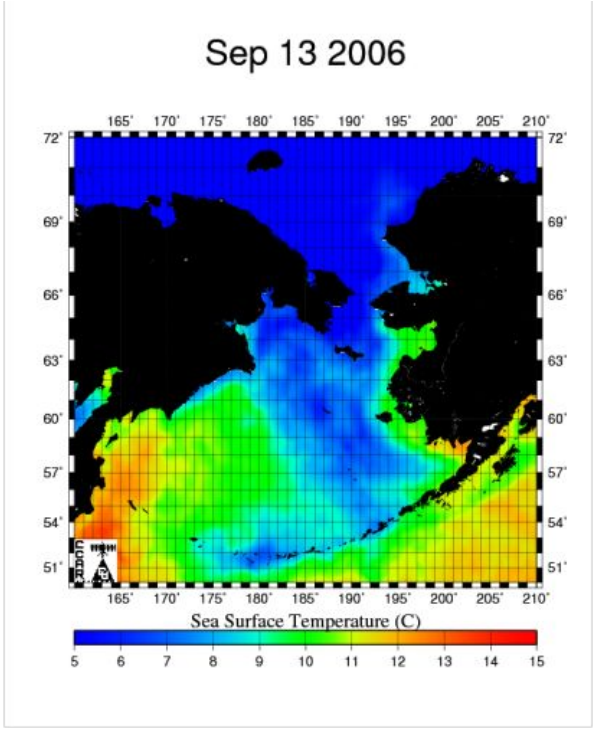

Stabeno, P.J., E.V. Farley, Jr., N.B. Kachel, S. Moore, C. Mordy, J. Napp, J. Overland, A. Pinchuk, and M. Sigler. 2012. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep Sea Res. II 65-70:14-30.

# Juvenile Salmon Move North (Sept. 2007)




Warm Year




Cold Year

Moore, S.E., L. Logerwell, L. Eisner, E.V. Farley, Jr., L.A. Harwood, K. Kuletz, J. Lovvorn, J.R. Murphy, and L.T. Quakenbush. 2014. Marine fishes, birds, and mammals as sentinels of ecosystem variability and reorganization in the Pacific Arctic Region. Pages 337-392, In. J.M. Grebmeier and W. Maslowski eds. The Pacific Arctic Region, ecosystem status and trends in a rapidly changing environment.

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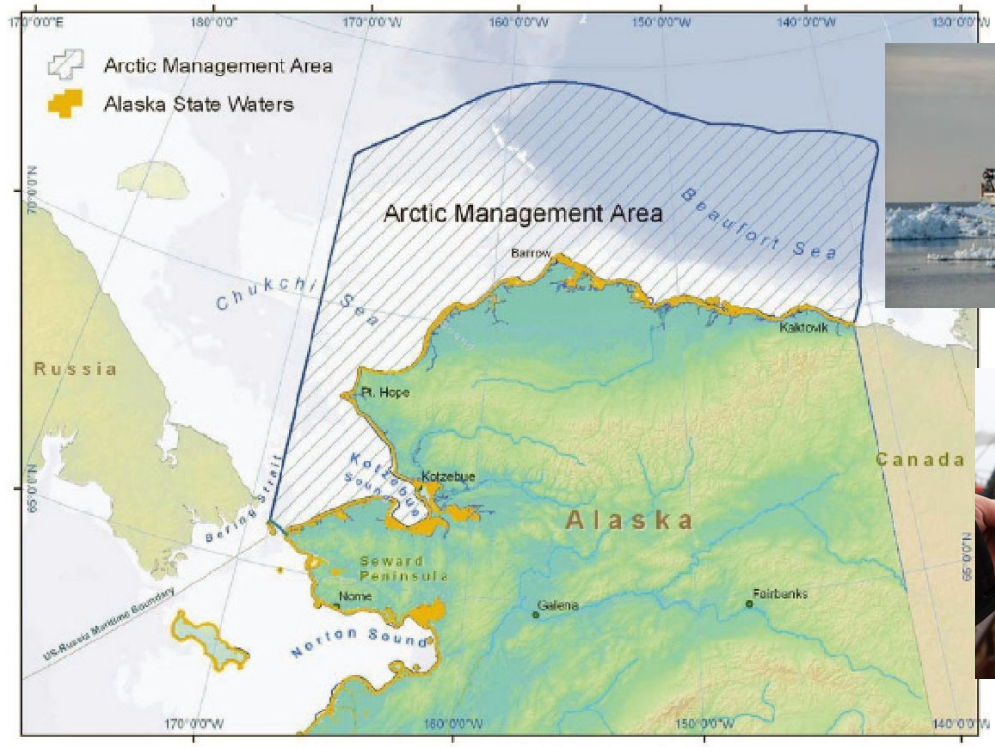
# Inclusion into LMR management advice




**Fishery Management Plan**

**for Fish Resources**

**of the Arctic Management Area**

North Pacific Fishery Management Council
605 W. 4th Avenue, Suite 306
Anchorage, Alaska 99501

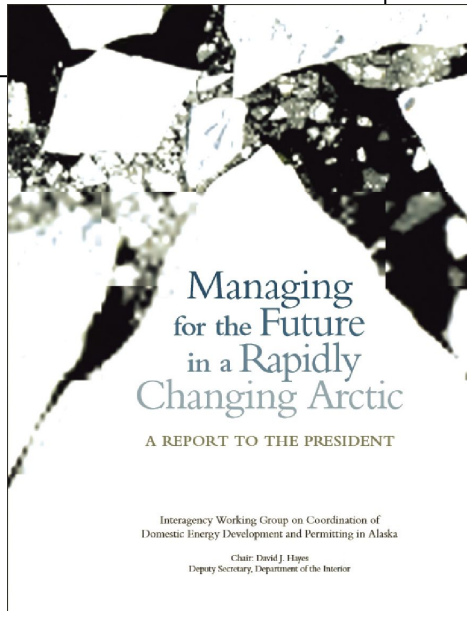
PHONE: (907) 271-2809
FAX: (907) 271-2817

August 2009

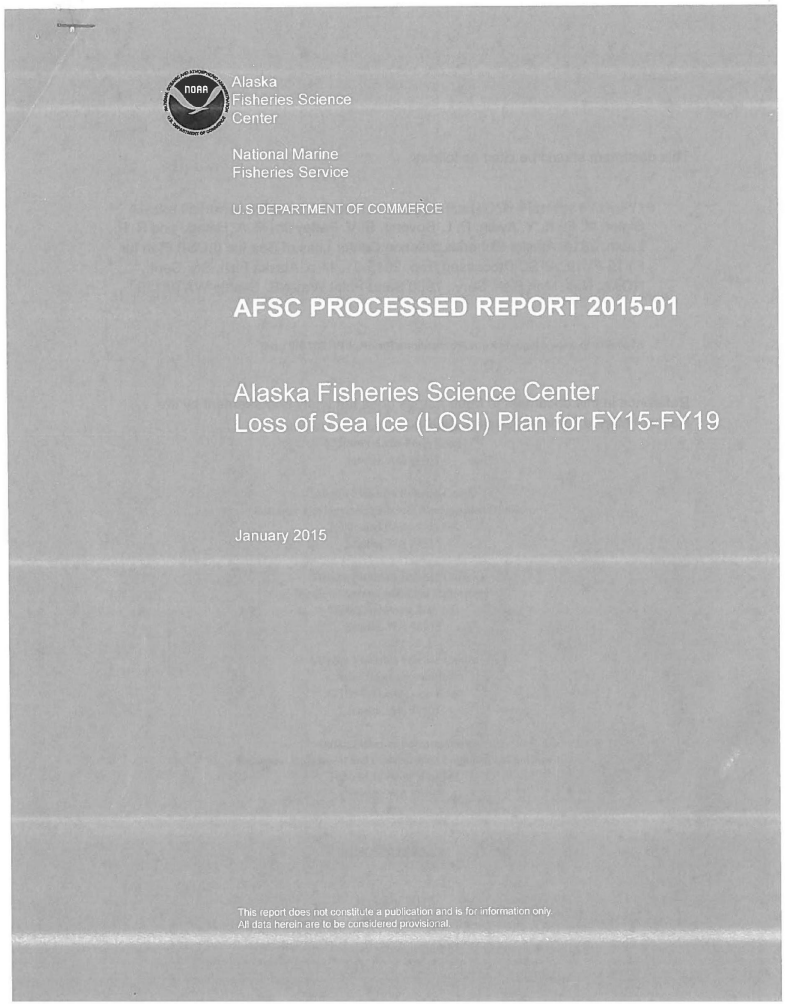

Arctic Fishery Management Plan (2009)

- Baseline data for: Arctic cod; Saffron cod; Snow crab
- Baseline data for oil and gas development, fishing, and anthropogenic influences.

  NOAA's Arctic Action Plan
- Strengthen foundational science – undertand impacts of climate change on ecosystem
- Improve management and stewardship of ocean and coastal resources



# Inclusion into LMR management advice




Extends surveys for fish and crab north.

Addresses goals within the NOAA Arctic Action Plan (NOAA 2014) and NOAA's Arctic Vision and Strategy (NOAA 2011) by providing information on how species distribution and marine food webs are altered by climate and seasonal ice in the northern Bering Sea and Chukchi Sea.

# Communication to the Public